FREQUENCY EFFECTS ON CORONA DISCHARGE TREATMENT

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The basics of corona discharge treatment have been covered in detail in various literature in the past. In this article we will examine in greater detail, certain system operational characteristics and their overall effect on system component life and consistent surface treatment.

The effects of the system's operating frequency on surface treatment have been the subject of much discussion in the past. However, this discussion has usually centered around the effects of frequency versus surface treatment on a quantitative basis, while the potential effects in other areas were not completely addressed.

It is generally accepted that the system's operating frequency has little to do with the treatment level that will be achieved - all other system parameters being equal. However, due to the fact that the corona load's characteristics vary with frequency; in the overall system picture, operating frequency can and does play an important role in the success or failure of a corona treating system.

The corona load can be characterized as a resistive portion, the air gap, in series with a capacitive portion, the dielectric. This is true regardless of whether the dielectric is bonded to the ground roll, as in a conventional system, or to the electrode, as in a bare roll system. It is the capacitive portion of the load that is affected most by the system operating frequency and ultimately has a considerable effect on overall system performance.

The common denominator between all corona treating systems is that the power density required to deliver a given amount of treatment is basically the same for similar systems (i.e.: conventional or bare roll). Comparisons must not be made however, between dissimilar configurations due to the fact that bare roll systems are inherently less efficient than their conventional counterparts. This holds true regardless of the material being treated, although it is less apparent on the easier to treat materials such as polyethylene with no additives. The difference becomes quite striking however, on materials such as polyethylene containing high levels of slip and anti-block. In some cases these materials cannot be treated to the desired levels on a bare roll system regardless of the power density applied.

The main difference then, is how a particular manufacturer delivers the necessary power to the corona, at his particular system operating frequency. Table 1 is a comparison between two systems, both operating on the same treating station, at different system operating frequencies. The system configuration is a conventional one consisting of a silicone rubber covered treater roll with 150 sq. in. of electrode area, running on a 5.0kW power supply. The calculations used to derive this table assume a power factor of .35 for the 9.6kHz system, which would be typical.

TABLE 1

FREQUENCY	LOAD P.F.	KVA	KW	ELECTRODE VOLTAGE
9,600 Hz	.35	14.3	5.0	17,000 Volts Pk
20,000 Hz	.61	8.2	5.0	9,700 Volts Pk

The voltages in the electrode voltage column are in peak volts which represent the stresses on the dielectric material being used.

As can be seen from this table, both the kVA and the electrode voltage requirements to deliver the same power to the corona are quite higher at the lower frequency. The higher kVA requirement translates to a larger system since the high voltage transformer may have to handle the additional kVA requirement while the higher electrode voltage requirement translates to significantly higher stresses on the dielectric material at the lower frequencies.

Some manufacturers of equipment at the lower frequencies have compensated for the inherently low power factor of the load by incorporating "power factor correction" devices into the high voltage transformer. By doing this, the power supply is no longer required to deliver the kVA requirement of the load since the "power factor correction" device does. With this type of system it is possible to operate at a higher overall system power factor, thus decreasing the kVA requirement of both the power supply and the high voltage transformer. However, this does not reduce the voltage requirement at the electrode(s) in the station since the actual "load power factor" cannot be changed.

Typically, the "power factor correction device" consists of an inductor (coil) in series with the output of the high voltage transformer. This inductor functions to cancel out some of the capacitive portion of the load for the power supply, effectively making the power supply "think" it is operating into a higher power factor load. Table 2 shows the same load as Table 1, with the power factor corrected to .61 as in the 20kHz system.

TABLE 2

FREQUENCY	LOAD P.F.	KVA	KW	ELECTRODE VOLTAGE
9,600 Hz	.35	14.3	5.0	17,000 Volts Pk
9,600 Hz	.61	8.2	5.0	17,000 Volts Pk
20,000 Hz	.61	8.2	5.0	9,700 Volts Pk

As can be seen from the above table, even though the power factor has been corrected to equal that of the 20 kHz system, the voltage stresses on the system dielectric have not changed. This inherently higher electrode voltage requirement not only contributes to reduced dielectric life, but also necessitates a larger station to accommodate the greater distances that must be maintained between high voltage and ground, to prevent arc-over.

Since it can be seen from the previous discussion that it is much better to operate at higher frequency than to correct for the lower frequency, the question usually arises as to why not operate even higher than 20 kHz. The answer to this is simple: as the frequency is increased above 20 kHz, the electrode voltage requirement further decreases, making the air gap much more critical.

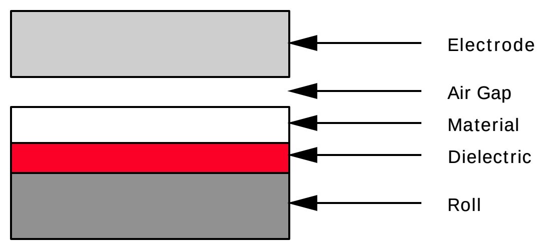
A point will be reached where it is nearly impossible to maintain an air gap of sufficient consistency and narrowness to insure consistent treatment across the width of the web being treated. Furthermore, the electrode area requirement for proper impedance matching grows smaller and more power is forced into less area, resulting in an inefficient corona with individual "streamers" shooting from the electrode rather than a smooth consistent glow.

Operating at higher frequencies can have other advantages as well, depending on the type of material being treated. The tendency for web wrinkling and backside treatment can be reduced, and improved treatment of metallized surfaces can result.

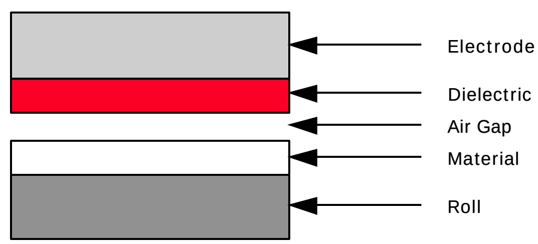
Certain materials are quite sensitive to corona treatment in that they tend to wrinkle as they pass through the corona. This wrinkling effect causes backside treatment and poor adhesion on the treated surface due to the striping effect where the wrinkles occur. The materials usually affected most by this phenomenon tend to be of light gauge, running at very low web tensions. It has been seen during lab testing of these types of materials, that several factors can influence this tendency. One of these factors is the voltage across the material itself, which ultimately relates to the electrode voltage applied to the system. As this voltage increases, so does the material's tendency to wrinkle when passing through the corona - especially in bare roll applications. This tendency can be further aggravated by the use of some "segmented" type bare roll electrodes since the area across the web is not exposed to the corona "all at once". With all segmented bare roll systems, certain areas of the web are treated before other areas, in "lanes". It is well known that corona treatment enhances the static charge on the material being treated, and when various "lanes" of the material being treated are exposed before others, a difference in static charge between these areas results.

The net result of this difference is that wrinkles can occur in the "downstream lanes" before they pass through the corona, causing backside treatment and wrinkles in these areas. When this is a problem, special static charge equalizing nip rollers must be installed within the station, prior to the material's passing through the corona. In many cases this is accomplished quite easily.

Although the wrinkling problem has occurred more often in bare roll systems, it is certainly not limited to them. Certain conventional applications are prone to this problem, especially when the material's tendency to wrinkle is mainly due to the voltage drop across the material, rather than the differences in static charge. These systems tend to utilize dielectric materials with high dielectric constants such as ceramic rather than the mid-range materials such as silicone rubber and epoxy. The reason for this can be seen by looking at a cross-section of the overall corona load as shown in Figure 1.



Conventional Cross-Section



Bare-Roll Cross-Section

Figure 1

Consider an application involving the treatment of a low density polyethylene web with the dielectric constant of the polyethylene being approximately 2.0. The typical ceramic covered roll has a thickness of about 50-60 mils of material and the dielectric constant can be as high as 10, while a typical silicone rubber covered roll has a thickness of 80 mils and a dielectric constant of 3. The relationship between these applications is depicted in TABLE 3 below.

TABLE 3

System Frequency: 9.6 kHz

MATERIAL	CONSTANT	THICKNESS	VOLTAGE ACROSS 2 MIL WEB
Ceramic	10	50 Mils	2,100 Volts Pk
Silicone	3	80 Mils	470 Volts Pk

The above peak voltages are for a typical 9.6 kHz system operating at 13 kV pk across the dielectric, and relate to the system depicted in TABLE 1.

The overall voltage across the web, and resulting tendency for wrinkling, blocking, and backside treatment can be further reduced by operating at 20 kHz instead of 9.6 kHz as depicted in TABLE 4 below.

TABLE 4

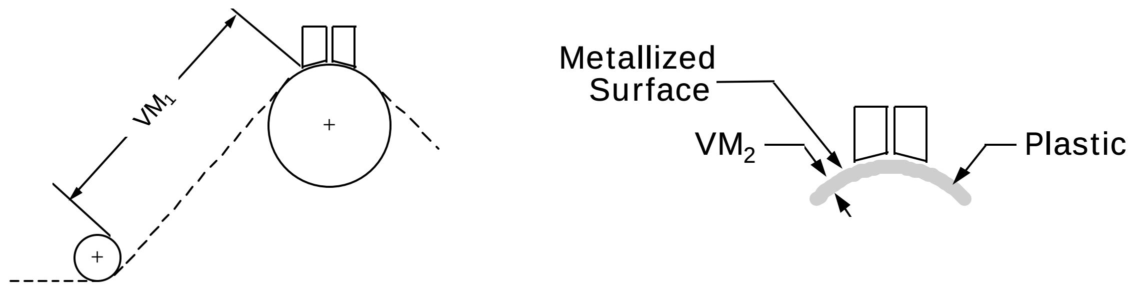
System Frequency: 20 kHz

MATERIAL	CONSTANT	THICKNESS	VOLTAGE ACROSS 2 MIL WEB
Ceramic	10	50 Mils	736 Volts Pk
Silicone	3	80 Mils	160 Volts Pk

Again, relating back to TABLE 1, it is possible to operate at a reasonable system power factor and electrode voltage with silicone rubber as the dielectric material when a system operating frequency of 20 kHz is utilized. This results in a system with the least likely possibility of wrinkling, blocking, and backside treatment, and the lowest operational stresses on the dielectric materials - resulting in increased system component life.

In some metallized material treating applications, operation at 20 kHz can also produce more consistent results, especially when the material being treated is only "lightly" metallized, having a somewhat high resistance, and therefore low conductivity. The reason for this lies in the station design itself. In many conductive substrate treating applications it is the metallized side of the material that is being treated. The metallized side of the material is grounded by idler rolls both upstream and downstream from the treating roll, with the plastic, non-conductor, isolating the metallized material from the backup roll as shown in Figure 2 below.

Since the metallized portion of the material has a certain resistivity, there exists a voltage difference between where the material passes through the corona and where it is grounded. This voltage difference is also impressed across the plastic portion of the material when it passes through the corona. In low frequency 9.6 kHz systems, this voltage difference can be high enough to cause both pin-holing of the plastic material and the "blowing off" of some of the metallized portion of the material as current flows in the material between the area under the corona and the nearest ground roll. This results in a "blotchy" appearance when the material is held up to light, as well as poor bond-ability of the metallized surface - which can be particularly evident in printing applications where the inconsistent wet-ability is visible in the printing on the surface of the material.



Voltage across the metallized surface between the electrode and the nearest ground roll must equal the voltage across the plastic or paper portion of the laminate. $VM_1 = VM_2$

Figure 2

However, having a system operating frequency of 20 kHz is not the complete answer in today's complex converting industry. The system must be easy to set-up and operate, and be capable of maintaining consistent treatment levels regardless of variations in operating parameters. In today's environment, the requirement of system compatibility with on-line computers and monitoring equipment is becoming more and more common.

Corotec Corporation offers a variety of power supplies ranging in output power from 500 watts up to, and including, 20 kW. The complete line of power supplies operate in the 20 kHz range and are available with a variety of options including the Corotec Power Density Control System. This system allows consistent treatment levels regardless of changes in line speed and web width. Line speed information is automatically fed to the system by the on-line tachometer, while web width information is dialed in by the operator. This information, along with the power density requirement of the particular material being treated, is used by the Power Density Controller to calculate and display the required output power for the application. In the automatic mode the Power Density Control also adjusts the power supply to the correct output power, eliminating operator guesswork. This system was the first of its type to be offered as both an option on Corotec equipment as well as a retrofit to existing equipment already in the field.

The high frequency power supplies offered by Corotec also make possible a unique type of bare roll treating station which utilizes the new "SRT" electrode system.

This system allows fixed-width bare roll treatment with an electrode that is highly efficient and low in cost compared to other bare roll systems. The electrode itself is extremely rugged and easy to adjust, and can be operated at power densities in excess of those achieved by ceramic electrodes, without overheating.

With the variety of materials and production parameters in use today, it is almost impossible to predict, without lab evaluation, the suitability of a particular corona treating system to an application. Once a system is installed and operating, problems encountered can be difficult, if not impossible, to solve - and can result in significant additional cost in terms of downtime and equipment changes. For this reason it is always best to have an application evaluated first, in a treating lab such as the one at Corotec Corporation, where a variety of treating configurations can be tested, and the best one for a particular application can be selected without bias towards any particular configuration. Although the exact production parameters cannot always be duplicated in a lab such as this, it is usually possible to get close enough for the tests to be of considerable value; and the production system can then be extrapolated from the test results.